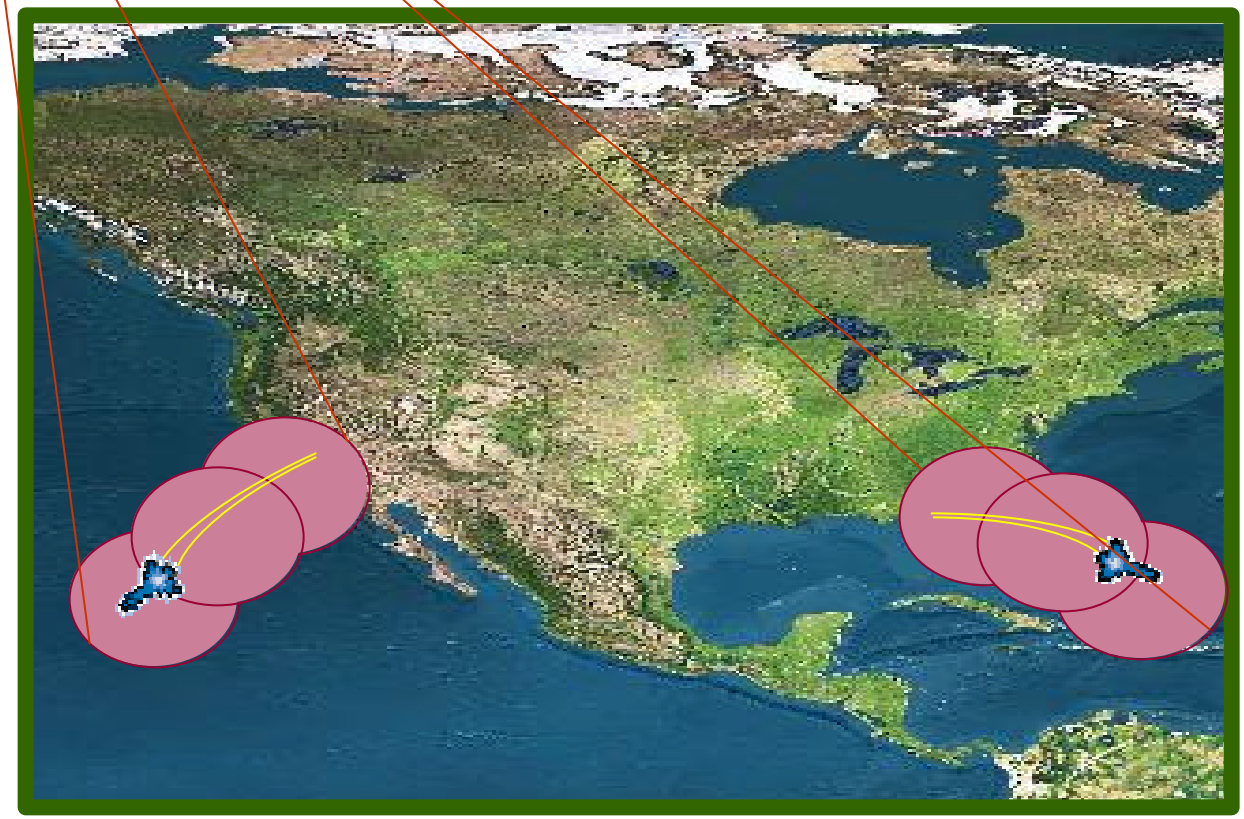
NASA
Space Network
Support for Range Safety



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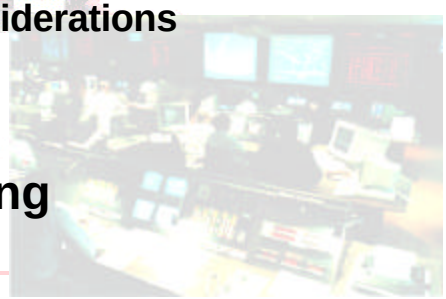
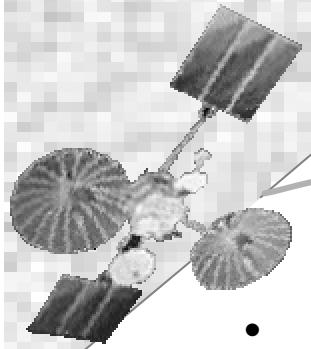


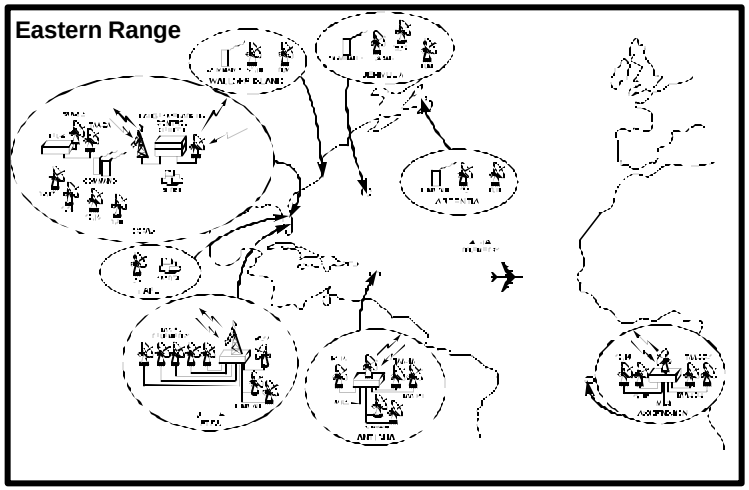


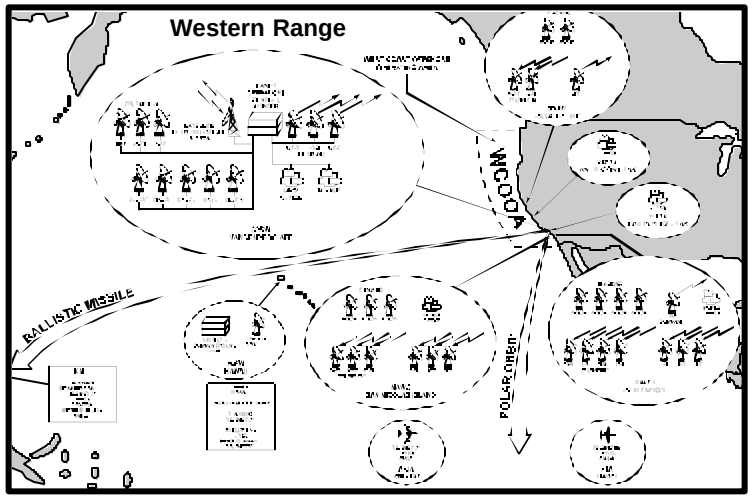
Introduction/Background

- **Range Safety Service can be defined as those communication services provided at the launch range to maintain the integrity of the launch system and avoid threat to Human Life**
- **The current system is effective, but could benefit from New Technology**
  - **Reduce Cost**
  - **Improve Flexibility**
  - **Increase Coverage**
  - **Maintain Reliability**
  - **Maintain Safety**

Introduction/Background

- **U.S Range Launch Activities trace back to the 1940's**
  - **Current Range Safety Systems are Ground-Based UHF Systems**
  - **Requires Significant Down Range Resources**



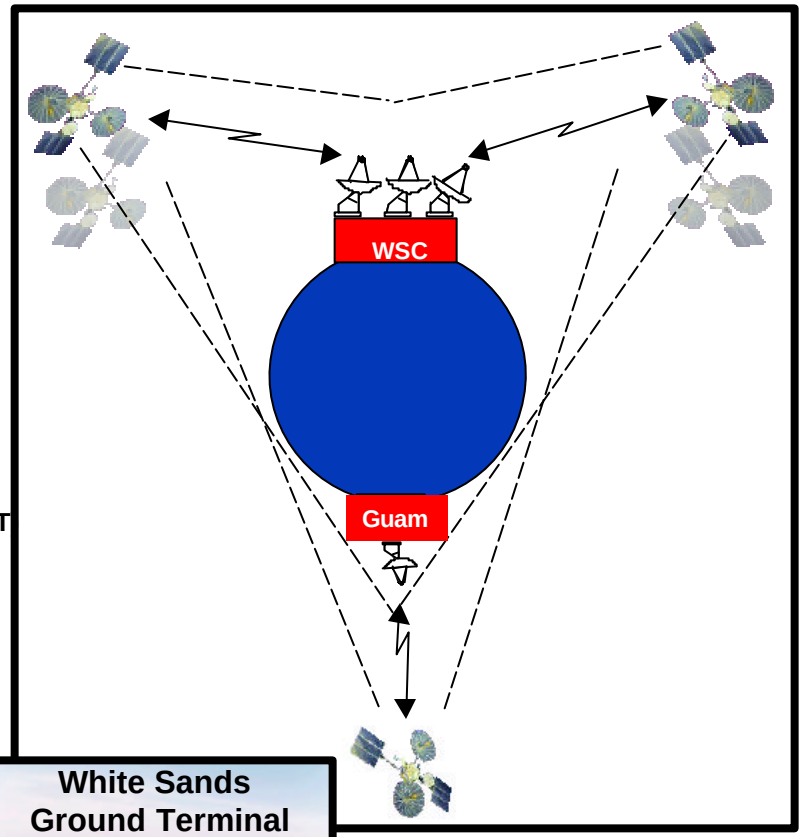


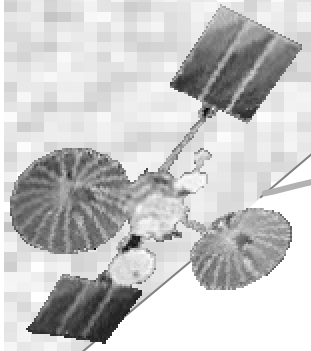
- **Investigations to provide Range Safety Service via Space-Based Platforms have been initiated**
  - **Tracking and Data Relay Satellite System (TDRSS) seems a viable "Stepping Stone" into the future Space-Based Platform support**
  - **The TDRSS includes a Ground Segment, Space Segment, and Supporting Elements**

SN/TDRSS Overview

Ground Segment

- The White Sands Complex (WSC) is the user interface to the TDRS spacecraft
- WSC is comprised of two co-located ground terminals located in New Mexico, USA and a remote extension in Guam
  - There is a total of six (6) Space Ground Link Terminals (SGLT
- Each SGLT is assigned a TDRS spacecraft and provides TDRS Control and User Services
- A three-TDRS constellation provides global coverage

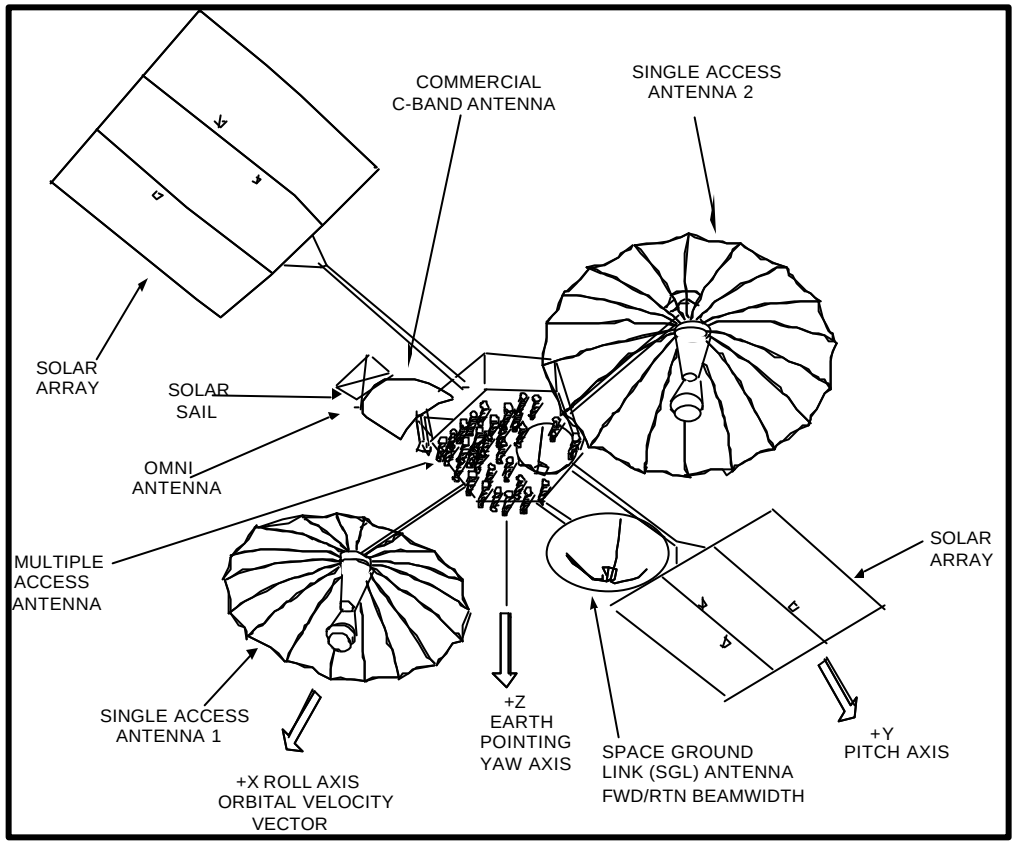




SN/TDRSS Overview

Space Segment/TDRS Spacecraft Description

- **Five operational TDRS spacecraft in geosynchronous orbit**
- **Strategic equatorial placement to provide global RF coverage for support of spacecraft, launch vehicles, and reusable vehicles**
- **TDRS operates in both the S- and Ku-Band frequencies. For this concept, focus is the S-Band frequency**
- **Forward S-Band Frequency: 2025-2120 MHz**
- **Return S-Band Frequency: 2200-2300 MHz**

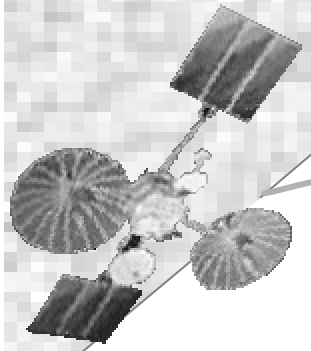


SN/TDRSS Overview

Future Space Segment

- **Three (3) new next generation TDRS spacecraft will be added to the constellation**
  - **TDRS H,I,J built by Hughes**
  - **Launched on the Atlas series launch vehicle**
- **The new spacecraft will support all current TDRS services plus:**
  - **Ka-Band frequency**
  - **Enhanced S-Band Multiple Access services**
- **The Range Safety concept will continue to focus on S-Band services**

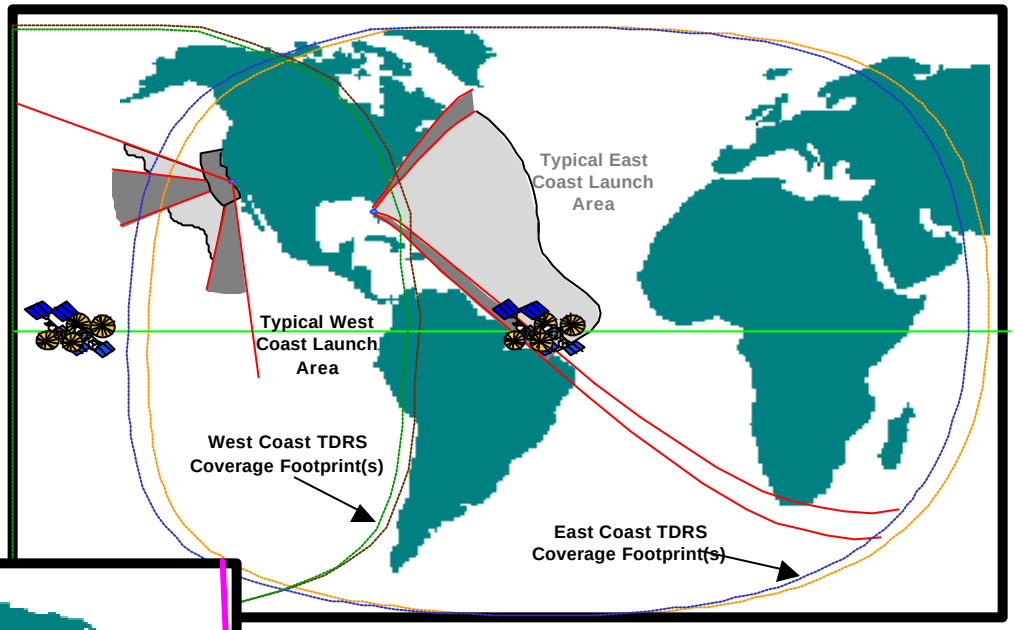
TDRS-H

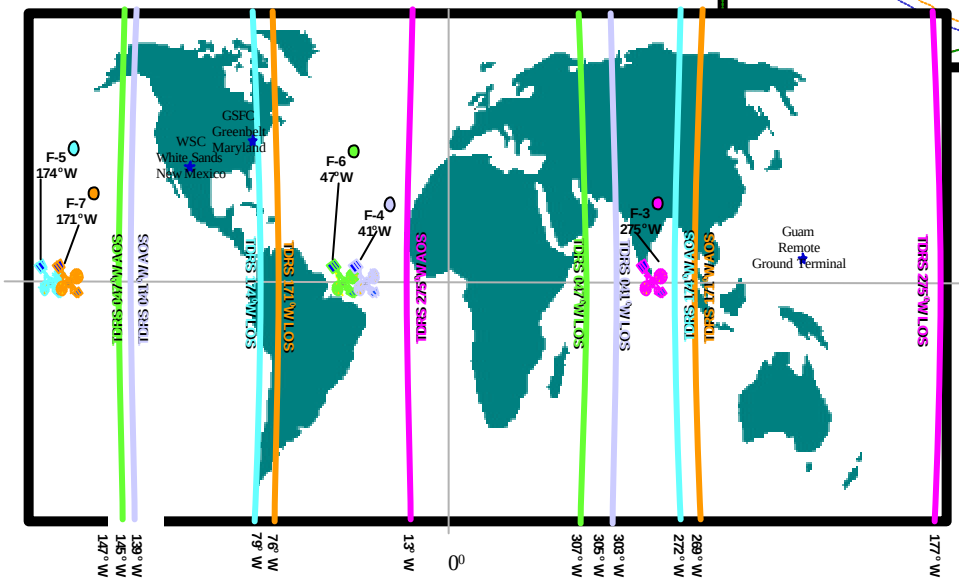


SN/TDRSS Overview

TDRSS Coverage

- **TDRS S-Band Footprint is ~700 miles in diameter at the Earth's surface**
- **Sufficient coverage to provide Range Safety services to various launch ranges without handovers**

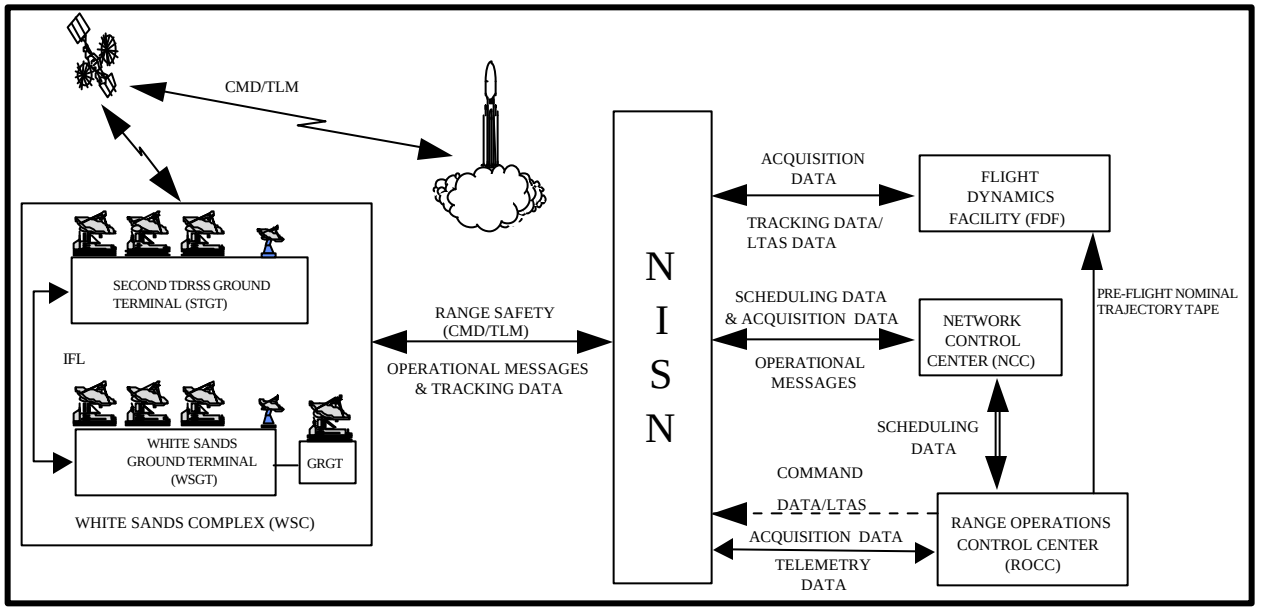




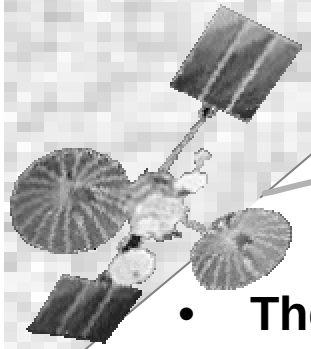
- **Five operational TDRS, each TDRS provides coverage over a certain range**
- **If TDRS services are used from Launch through Insertion, coverage can be provided with minimal handovers**

SN/TDRSS Overview

SN/TDRSS Support Elements



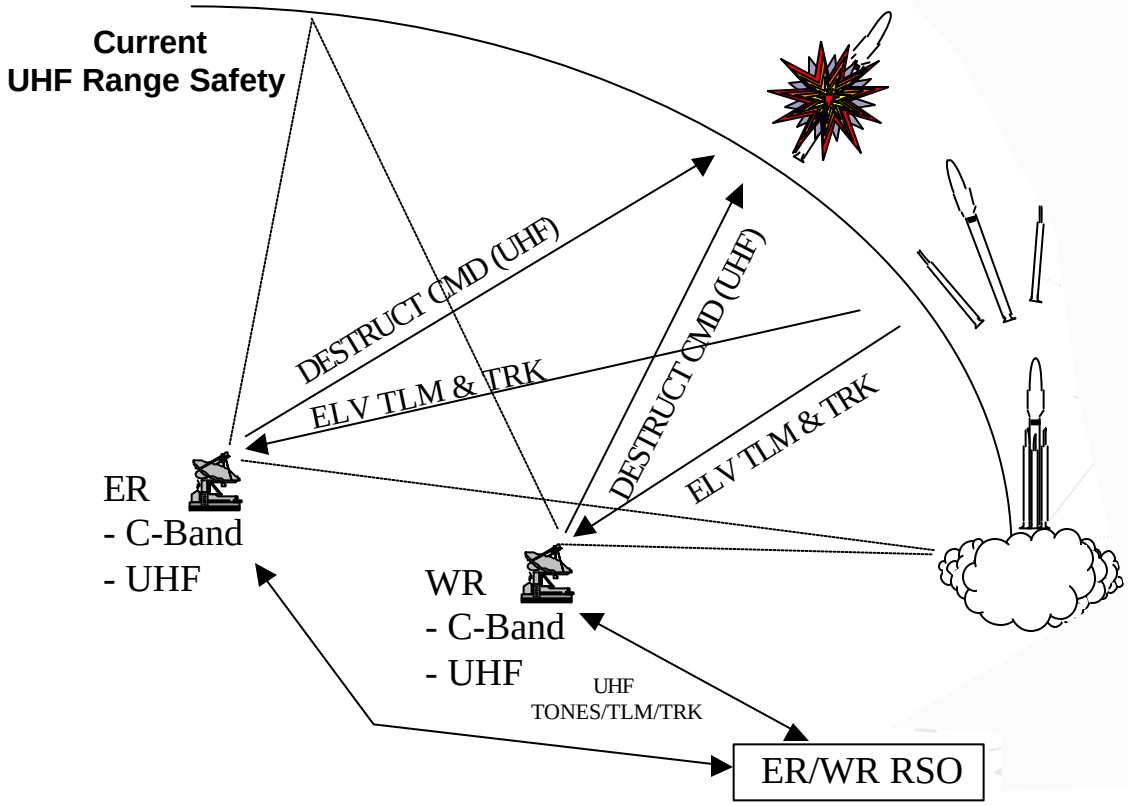
- **The SN support elements for Range Safety include: Network Control Center (NCC), Flight Dynamics Facility (FDF), and NASA Integrated Services Network (NISN)**
  - **NCC: Located at GSFC, the NCC is the point of contact for all networks planning, scheduling, and control**
  - **FDF: Located at GSFC, the FDF is responsible for TDRS and User spacecraft ephemeredes, tracking data, and TDRS pointing**
  - **NISN: Managed from MSFC with personnel at GSFC, the NISN provides all communication circuits between operations entities**



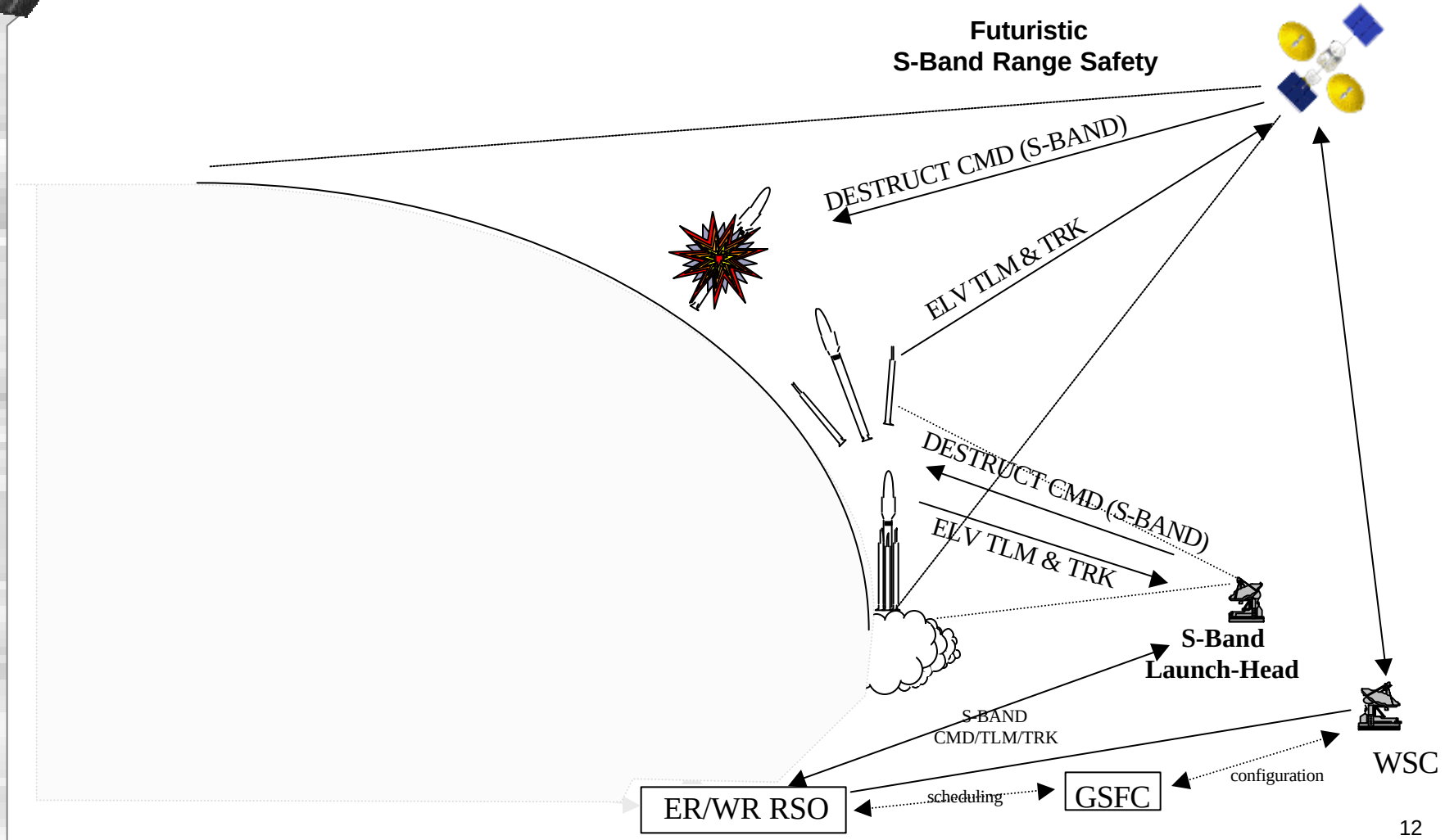
Proposed SN Range Safety Concept

- **The NASA concept was proposed to determine Technical and Operational Feasibility of vehicle flight termination with a Space-Based Platform, namely the NASA Space Network (SN)**
- **SN Support for Range Safety Concept**
  - **Transition from UHF Ground-Based system to a Space-Based S-Band System with compatible S-Band Ground Launch Head and Launch Vehicle Component**
  - **Eliminate Down Range Stations and provide Continuous Coverage through All Launch Phases through Orbital Insertion**
  - **The combination of the SN/TDRSS and the Launch Head will provide a "Seamless" Transition Over-the Horizon**
  - **Launch Head and TDRSS Radiate PN Spread Signals Simultaneously**
  - **Vehicle Transceiver able to track both Launch Head and TDRSS forward signals simultaneously and return telemetry with vehicle range safety parameters and position data (GPS)**

SN Range Safety
Concept Description

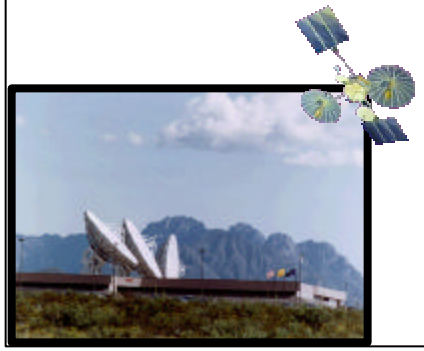


SN Range Safety
Concept Description



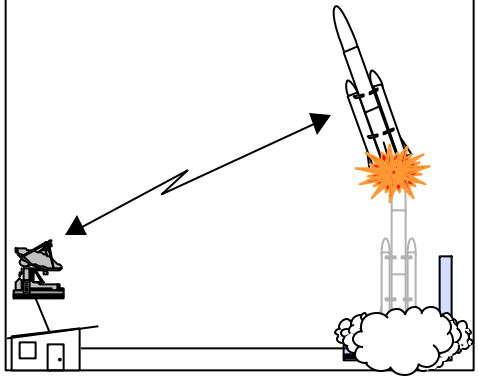
SN Range Safety
Main Components

Tracking and Data Relay Satellite System (TDRSS)



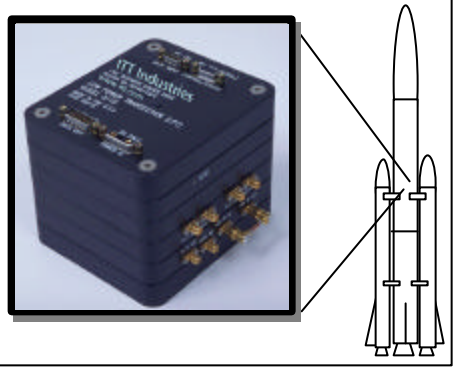
- PN Spread Forward Link; High power mode
- TDRS S-Band Footprint is ~700 miles in diameter at the Earth's surface
- Sufficient coverage to provide Range Safety services to ER or WR without handovers

TDRSS-Compatible Launch-Head System

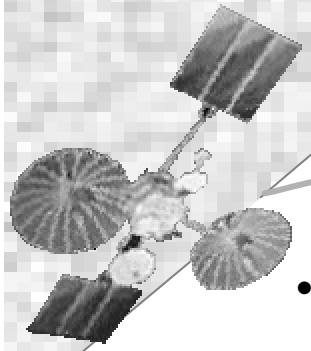


- S-Band TDRS Compatible
- PN Spread Forward Link
- Primary vehicle interface until Over-the-Horizon (OTH); Seamless transition from ground to space
- Pre-Launch Test Resource

Vehicle TDRSS-Compatible Transceiver

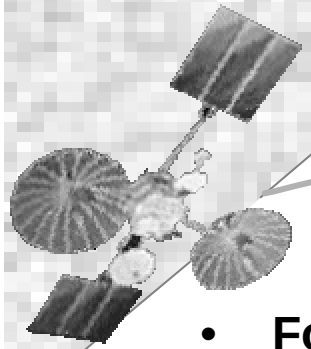


- S-Band TDRS Compatible Low Power Transceiver
- Fast acquisition
- Multi-channel receiver for simultaneous Forward links from the TDRS and Launch-Head
  - Use separate PN Codes
- Telemetry will provide vehicle status and position data from GPS



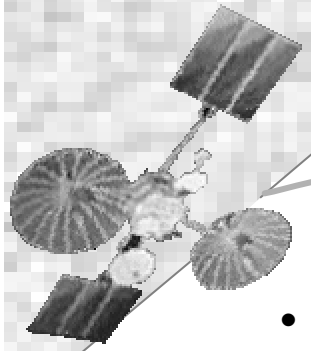
SN Range Safety Operations Scenario

- **On the launch pad, the Launch-Head is prime communications interface**
- **After launch and clear of initial interference (such as the Launch Tower), the vehicle acquires TDRS**
- **Launch-Head and TDRS simultaneously radiate S-Band PN-Spread forward signal (commands), same frequency**
- **Launch-Head loses link Over-the-Horizon, TDRS is prime communications interface**
- **Flight Vehicle will carry two multi-channel transceivers capable of tracking three TDRS Mode PN Spread Signals and up to eight GPS signals**
- **Telemetry will be relayed to the ground both directly to the Launch-Head (when available) from the vehicle and via the TDRSS**
  - **Including position data from GPS and onboard IMU**



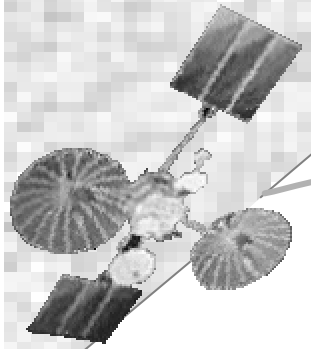
SN Range Safety
Specific Operations Considerations

- **Forward and Return Link Margins**
  - **Assumed antenna gain exceeded over 95% of the Vehicle RF Coverage Sphere**
  - **Assumed a Hybrid Coupler between antenna and two transceiver configuration**
  - **Data Rates Considered: 250bps Command/2.4kbps Telemetry**
  - **Forward Link Margin (command): ~10.8 dB**
    - » **Over 95% of the Coverage Sphere, link margin > 10.8 dB**
    - » **Remaining 5% of the Coverage Sphere, link margin <10.8 dB**
  - **Return Link Margin (telemetry): ~ 7.4 dB**
- **Data Latency**
  - **Current range requirement = 500 milliseconds**
  - **Testing with a simulated control center sent digital commands to WSC (processed, modulated) then transmitted via TDRS to a simulated vehicle: Round-trip closed-loop test = 340-370 milliseconds**
  - **Circuit routing design may reduce data latency**



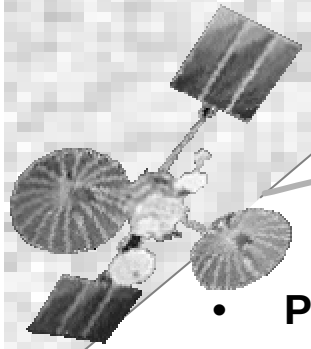
SN Range Safety
Specific Operations Considerations

- **Security Considerations**
  - **PN-Spreading the Forward Link**
  - **Command Data Structure being developed for optimal performance: command length, latency, data rate, link margin**
  - **Focus is to prevent unwanted flight termination**
- **TDRSS Reliability**
  - **TDRSS reliability is defined as Mean Time Between Failures (MTBF - divide the 10-cycle of TDRSS by the predicted number of failures)**
  - **Operational support $\geq$ 99.9%**
  - **Redundancy within the SN (ground/space)**
- **Cost Comparisons**
  - **Space-Based reduces cost**
    - **M&O costs spread over Multiple Users**
    - **Reduced Resources (equipment and personnel)**
    - **Quicker Turn-Around Time for next support**



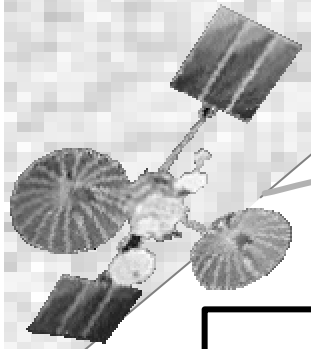
New Technology

- **Technology to support a Range Safety application is part of an ongoing NASA Technology Program**
- **The Low Power Transceiver (LPT) as applied for Range Safety**
  - **Modular design**
  - **Twelve-Channel (12) S and L-Band Receiver**
  - **For Range Safety: three channels configured TDRSS-Mode, eight GPS channels, one open channel**
  - **Fast Acquisition: < 1 Second**
  - **All receive channels configured as PN-Spread**
  - **Telemetry transmitted at S-Band, TDRSS BPSK Modulation**
  - **Transmitter Output Power Options up to 25 Watts (power will be a function of the telemetry data rate) and vehicle power**
  - **Size: 5x5x5 inches; Mass: 5 kg**
  - **Operating Temperature range: -30^0 to 75^0C**



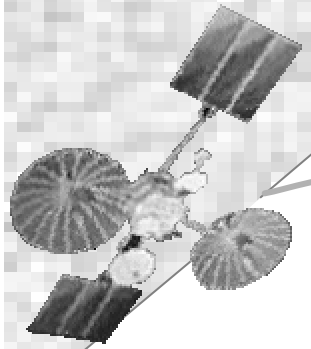
Proof-of-Concept Testing

- **Proof of Concept test will involve the SN, an S-band launch-head ground system, and the launch vehicle component (i.e., the LPT) on a flight vehicle**
  - **X-Vehicles (X-34, X-43)**
  - **High Performance Aircraft**
  - **Sounding Rockets**
- **Existing NASA resources (i.e., tracking station) would be augmented and used as a launch-head**
- **The vehicle component (i.e., LPT) will undergo environmental tests (shock, vibration, thermal vacuum)**
- **The Proof-of-Concept Program flight demonstration will demonstrate TDRSS-mode ground- and space-based forward and return links, as well as the capability to receive GPS**
- **Commands will be looped back internally and no connection with the vehicle Command and Data Handling (C&DH) system will be made**
  - **Looped back in the experiment package, not used for actual flight termination**



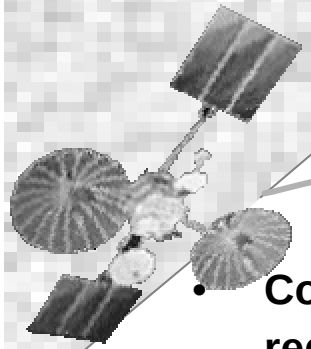
SN Range Safety Schedule

Timeframe	Event	Event Description
Feb 2001	**EM Range Safety Command Destruct Transceiver**	Complete development of next EM multichannel RS Transceiver
May 2001	**STS-107 Mission Payload Testing**	LPT manifested as payload on Space Shuttle. First opportunity to observe simultaneous signal processing and over-the horizon ground-to-space transition thereby simulating RS concept
March - July 2001	**EM Testing:** **Compatibility** **Environmental**	Conduct series of testing to verify compatibility with the SN. Also conduct shock, vibration, thermal, and dynamic pitch/yaw/roll environmental tests.
Aug 2001- Aug 2002	**Test Flights:** **High-Speed Aircraft** **Sounding Rocket** **RLV or X-Vehicle**	Perform experiments of the SN RS concept as a payload on a flight vehicles. Current vehicles being considered include high-speed aircraft, a sounding rocket, or as a payload on an RLV/X-Vehicle.



Technical Challenges

- **Optimal Command Data Structure considering command length, latency, data rate, link margin, and security**
- **Mitigating multi-path on Launch Pad through Liftoff**
- **Optimum power level differences between the Space and Ground-Based assets**
- **Specific Space-Based Range Safety operations have not been conducted**
- **Prove that the LPT is a valid component for the Range Safety Application**



Conclusion

- **Competitive World Launch Market drives increases in flexibility and reduction in operating costs**
- **Extensive support infrastructure is costly to maintain and operate, thereby limiting launch turnaround time, launch site flexibility, and coverage area**
- **GSFC SN Project Office concept grafts new technology with a reliable, proven, and operational Space-Based platform**
- **GSFC, in conjunction with other NASA organizations and industry, is embarking on a development and test program**
- **A full proof-of-concept phase is evolving and is expected to culminate in flight demonstration tests with actual launch vehicles**
- **Concept focuses on Maintaining Public Safety**
- **Visit the NASA GSFC Mission Service Program Office and Range Safety Websites: Mission Service Program Office : http://nmsp.gsfc.nasa.gov/ Range Safety: http://nmsp.gsfc.nasa.gov/range/range.html**